Lecture 3

Building Blocks of Integrated Circuits

March 9, 2005

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Outline

Transistor

Semiconductor fundamentals

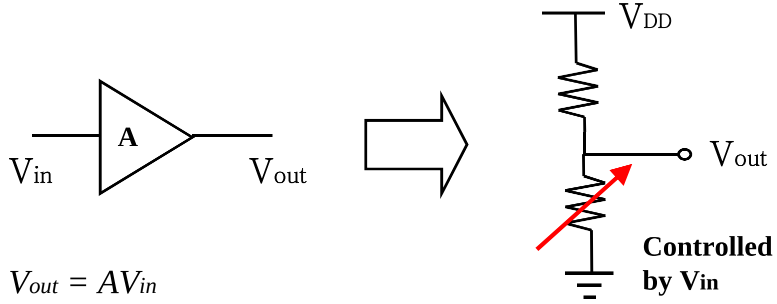
MOS Transistor

BJT

How to design a gain element

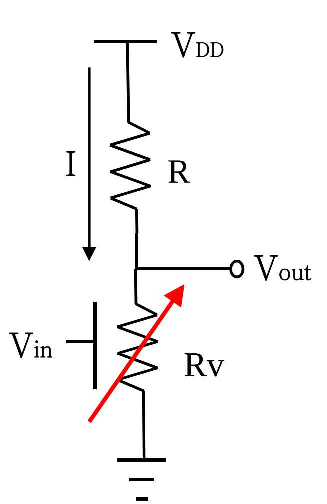
When we are going to design amplifiers for a varying gain,

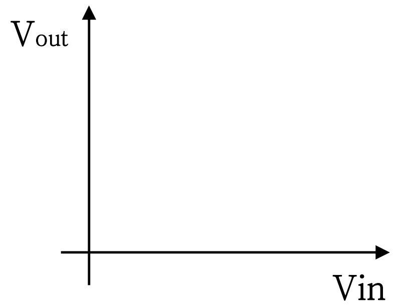
what is the simplest way?



$V_{out} = AV_{in}$

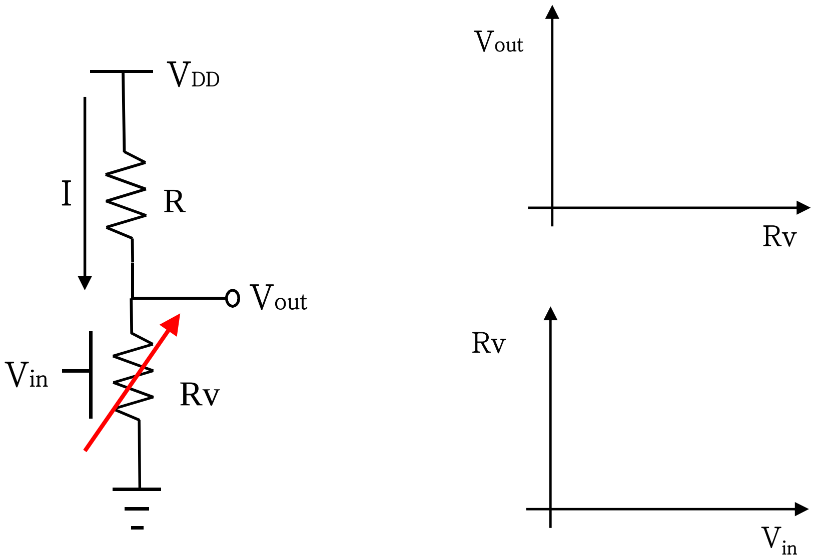
Variable Resistor





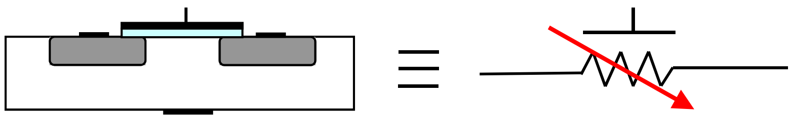
$$V_{out} = \frac{R_v}{R + R_v} V_{DD}$$

Variable Resistor



Meaning of Transistor

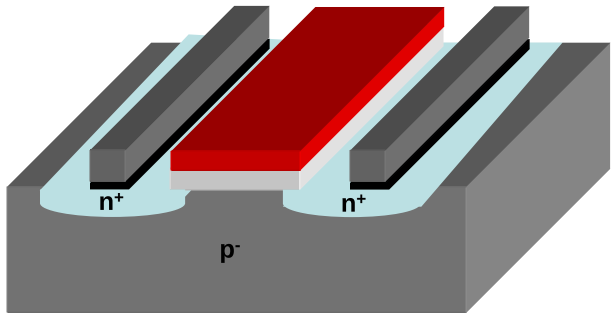
$$R_V \propto \frac{1}{V_{in}}$$



How to design a gain element

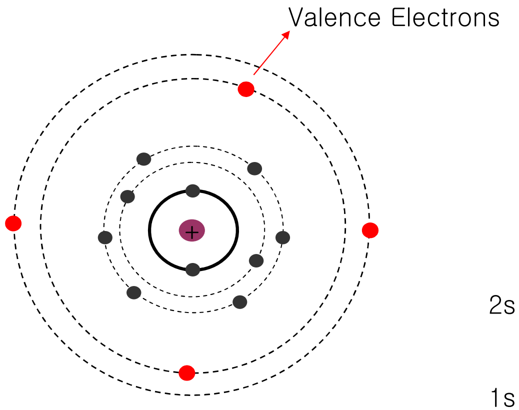
By similar approach, we can also derive an exponential relation between V_{in} and V_{out}. In this case, you can see the characteristic of BJT.

Structure of MOS Transistor

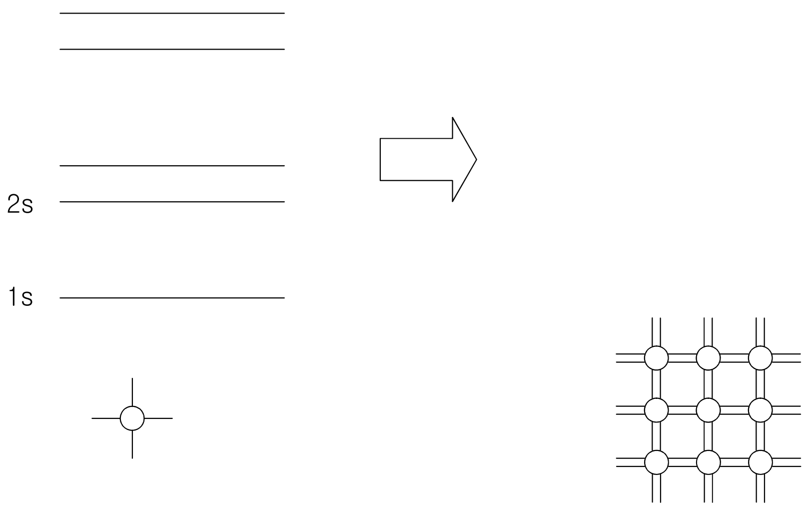


Fundamentals of Semiconductor

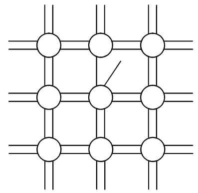
- Si : 14 → $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

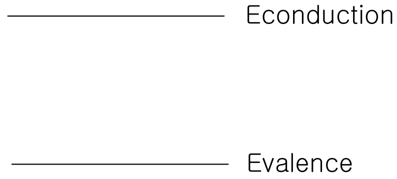


Si in Crystal



Energy Bands





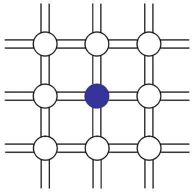
Electron – hole pair

Energy Bands of Different Materials

	Insulator	Semi-conductor	Conductor
Energy-band			
Free Electrons:			

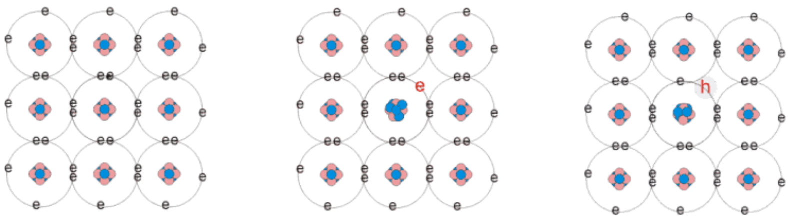
Adding Impurities

At room temperature, $n_i \sim= 10^{10} / cm^3$, # of atoms = $10^{22}/cm^3$
→ one out of_________ atoms is ionized at room temperature.

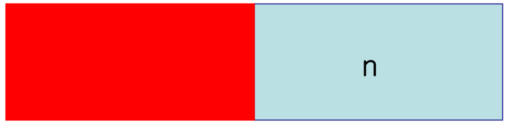


p, p+, p−
n, n+, n−

Doped semiconductors



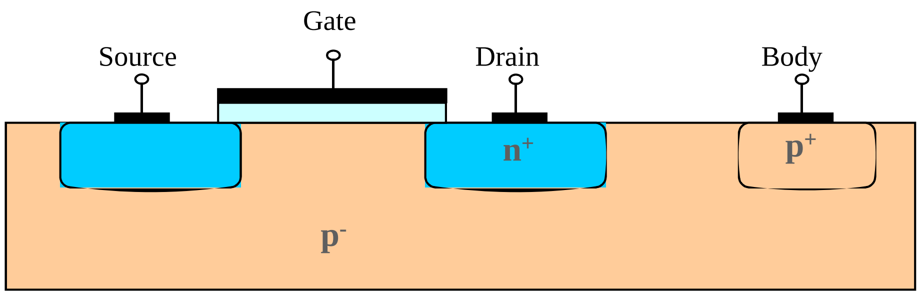
P-N Junction



Diffusion :

Drift:

Operation of MOS Transistor



Linear Region: $$I_D = \mu_n C_{ox} \frac{W}{L}\left[(V_{GS} - V_T)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

Saturated Region: $$I_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}\left[(V_{GS} - V_T)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

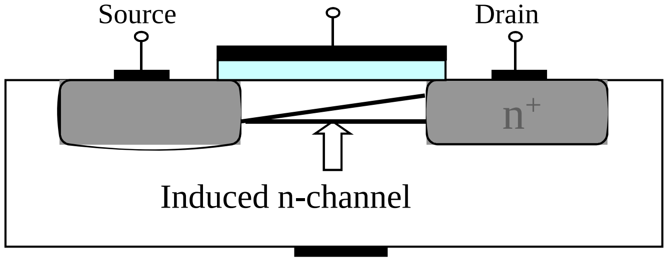
Intuitive Understanding of I-V

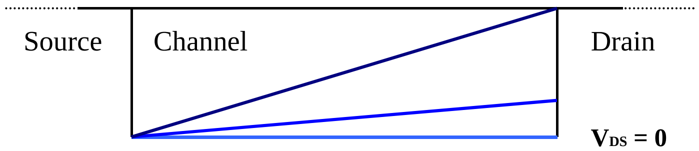
$$I = v \cdot Q$$

$$Q = CV$$

Operation of MOS Transistor

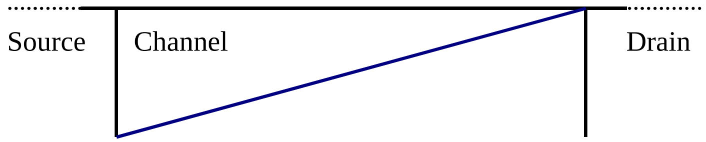
3. Operation as V_{DS} is increased



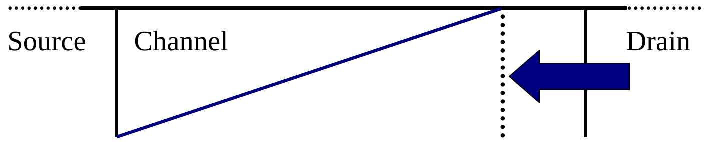


2nd order Effect : Channel Length Mod.

4. Operation as V_{DS} is increased beyond V_{DSsat}

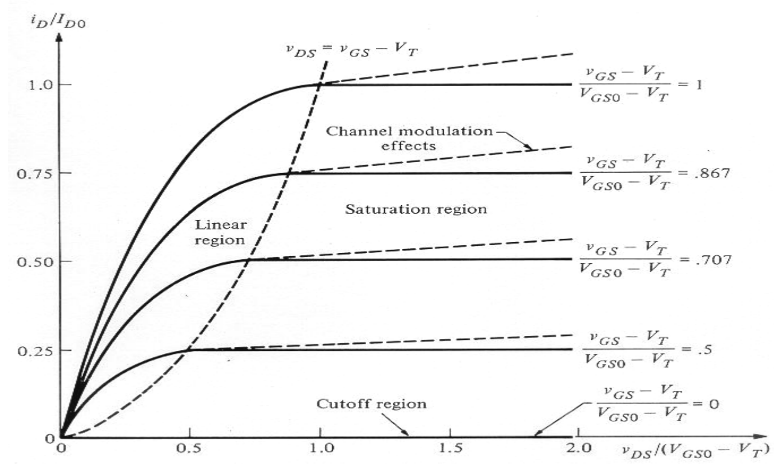


Channel length modulation occurs,

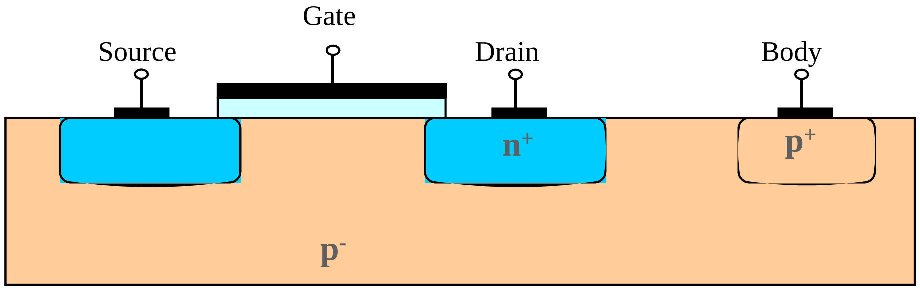


Operation of MOS Transistor

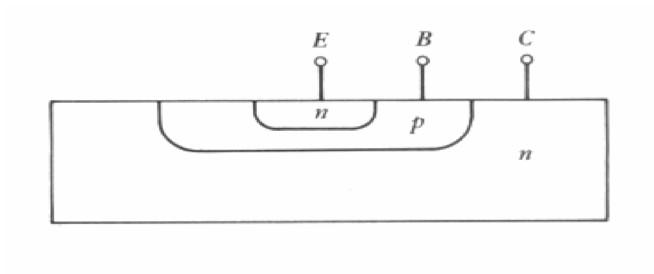
$$i_D = \frac{1}{2} K_n \frac{W}{L} (V_{GS} - V_T)^2 (1 + \lambda V_{DS})$$



2nd Order Effects: Body Effect



BJT Basics



Conduction mechanism in a bipolar transistor is made of the _______ **CARRIERS** flowing through the base region.

Currents are flowing through semiconductors junctions, within the crystalline structure. Not a surface effect.

Comparison

	MOS	BJT
Current flow	_____ carrier by ________	_____ carrier by ________
Model	_____-controlled current source	_____ -controlled current source
I-V characteristics	Square	Exponential